THE BEHAVIOR OF NITROGEN ISOTOPES IN ACIDIFIED FOREST SOILS IN THE CZECH REPUBLIC

F. BUZEK, J. ČERNÝ and T. PAČES

Czech Geological Survey, Klárov 3, 118 21 Prague 1, Czech Republic

Abstract. The effects of atmospheric deposition on N cycling in acidified soils were studied at three spruce and one beech forested sites in the Czech Republic. Nitrogen content and δ¹⁵N were monitored in bulk and throughfall precipitation, needles, leaves, soils and soil solutions. Changes in soil NO₃⁻ production, effect of admixing of atmospheric N in spruce forest and N consumed in deciduous forest are described using changes in δ¹⁵N fractionation of mineralized N in soil. Admixing of atmospheric NH₄⁺ can be identified at low concentrations of exchangeable NH₄⁺. The δ¹⁵N ratio of atmospheric NO₃⁻ input is on average by 2‰ less negative than the δ¹⁵N ratio in soil water; admixing changes the δ¹⁵N of soil NO₃ detected in lysimeters.

Keywords: ammonium, Czech Republic, natural abundance ¹⁵N, nitrate, nitrogen cycling, forest soil acidification

1. Introduction

Nitrate is rarely leached from temperate and boreal coniferous forests at sites with low atmospheric N input. In these forests, rich mycorrhizal flora uses N directly in litter and returns it to plants bypassing the microbial population. In central Europe, however, NO₃⁻ ions in soils are not fully consumed because of high atmospheric N input, decreasing denitrification capacity in acidified soil, and land-use changes replacing deciduous trees by conifers. Conifers have at least 10 times lower capacity to consume NO₃⁻ than do deciduous trees or herbaceous plants. Consequently, the forests cannot cope with high NO₃⁻ atmospheric deposition, which results in a higher NO₃⁻ production in central European soils (Schulze, 1996).

Natural abundance ¹⁵N is used in this study to examine qualitatively or semi-quantitatively processes of N cycling in forest ecosystems. The advantage of natural abundance studies is their easy application at any site without additional work and costs connected with labeling; the disadvantage is a relatively low natural variation in N isotope ratios, which sometimes results in an overlap between the source and receiver pool signals making it difficult to estimate the rates of N transformations (Nadelhoffer and Fry, 1994).

The objectives of the ¹⁵N monitoring were: 1) identification of atmospheric N in N compounds of soil solutions, and 2) separation of natural ¹⁵N enrichment caused by biological transformation from the effects caused by variations in atmospheric input.

2. Materials and Methods

2.1. Sampling site

Three sampling sites, Načetín (770 m a.s.l.), Červená Jáma (800 m a.s.l.) and Jezeří (550 m a.s.l.) are located in the Ore mountains at the Czech-German border near the city of Most. This region belongs to the "Black Triangle" - the most polluted and most acidified

region of Europe. The highest annual input of acid emissions occurred during the period of 1978 to 1982 (108 kg S ha\(^{-1}\) yr\(^{-1}\), 13 kg of N ha\(^{-1}\) yr\(^{-1}\); Pačes, 1985). The acidification gradually has declined. The atmospheric input during our investigation period of 1995 - 1996 was 35 kg S ha\(^{-1}\) yr\(^{-1}\) and 12 kg of N ha\(^{-1}\) yr\(^{-1}\) (Černý et al., 1998). The fourth site, Šalačova Lhota (557 to 744 m a.s.l.), is located in the Bohemian-Moravian Upland (160 km southeast of the Erzgebirge) where the input of acidic emissions has been comparatively low. The input was 21 kg S ha\(^{-1}\) yr\(^{-1}\) and 8.6 kg of N ha\(^{-1}\) yr\(^{-1}\) during the 1975 - 1990 period (Pačes, 1985). The input slightly increased to 26 kg S ha\(^{-1}\) yr\(^{-1}\) and 11 kg of N ha\(^{-1}\) yr\(^{-1}\) during our investigation period (Fotová, 1996). The bedrock and soils are very similar at all four sites. Prevailing bedrock is granite and quartzite. Soils range from Dystric Cambisols to Cambic Podzols.

Načetín, Červená Jáma and Šalačova Lhota are covered with 40 to 60 year old spruce (Picea abies) forest. Jezefí is covered with 100 year old beech forest (Fagus sylvatica). In the Erzgebirge, the spruce forest is damaged by acid emissions to the extent of a complete dieback. Most of the area has been deforested. Our spruce sites represent just remnants of the original spruce forests. The spruce forest at Šalačova Lhota appears healthy; however, slight symptoms of decline have been observed since the beginning of our observation in 1976.

The soils in the Erzgebirge sites have pH\(_{\text{EC}}\) from 2.6 to 4.2 and the cation exchange capacity (CEC) is very low (0.13 to 1.6 meq kg\(^{-1}\)). These properties are not significantly different from the less acidified site of Šalačova Lhota where pH\(_{\text{EC}}\) varies from 2.7 to 3.4 and CEC varies from 0.27 to 1.6 meq kg\(^{-1}\).

The Šalačova Lhota catchment has an area 1.68 km\(^2\), fully covered by spruce. The concentration of NO\(_3\)-N in runoff is less than 0.2 mg L\(^{-1}\). The beech site of Jezefí is situated in a 2.61 ha catchment on the eastern slopes of the Erzgebirge mountains facing one of the most industrialized regions in the Czech Republic. The average NO\(_3\)-N concentration in runoff is less than 0.1 mg L\(^{-1}\). A small subcatchment (0.29 km\(^2\)), Červená Jáma, in the upper part of the Jezefí catchment is spruce-forested. The average NO\(_3\)-N concentration in runoff is about 1 mg L\(^{-1}\) (Fotová, 1996).

2.2. Sample Collection

Rainfall and throughfall were sampled using polyethylene funnels. Cumulative monthly samples were collected. Thymol was added to collectors to minimize microbial activity in the water samples during the sampling period (Gillet and Ayres, 1991). Before the determination of \(^{15}\)N, rain and throughfall samples were examined for contamination with bird droppings by testing the samples for phosphate; contaminated samples were rejected.

Two sets of suction lysimeters were installed in 1995 at a depth of 90 cm at the Načetín stand. The lysimeters were placed at an increasing distance from a tree (numbered from Cal 1 to Cal 4). The area where the lysimeters were installed is covered with Calluna vulgaris var. nitens.

Soil samples were taken from five profiles in the vicinity of the lysimeters and from three profiles at each of the other sites (Šalačova Lhota, Červená Jáma, and Jezefí). Three levels (0-5 cm, 5-15 cm, and 15-40 cm or 15-80 cm), corresponding to A, Bv or C soil horizons, were sampled.

Soil samples were placed into polyethylene bags and frozen on the site at \(-80^\circ C\) using